

Carrier Air Wing Mishap Reduction Using a Human Factors Classification System and Risk Management

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Introduction: In 1998, the Navy's center of excellence for advanced air wing combat operations, namely the Naval Strike and Air Warfare Center (NSAWC), had a spike in Class A flight mishaps. The spike triggered an intense review of prior mishaps and current mishap-reduction practices using the Human Factors Analysis and Classification System (HFACS). The review resulted in NSAWC instituting a comprehensive multifactorial mishap reduction plan applying Operational Risk Management (ORM) precepts. **Methods:** This is a nonrandomized investigational study with use of a historical comparison population. The Class A mishap rate per flight hour covering 10 yr prior to the mishap reduction efforts was estimated and compared to the Class A mishap rate per flight hour for the 10 yr after implementation using Poisson regression. **Results:** Combined Fleet and NSAWC data shows a 27% reduction in mishap rate, but the 21% reduction in the Fleet alone was not statistically significant. The mishap reduction at NSAWC was statistically significant with an 84% reduction. Fallon carrier air wing mishap rates post-ORM mishap reduction efforts are approaching those seen in the Fleet, but are still elevated overall (3.7 vs. 2.4). **Conclusion:** The incidence rate ratio was 80% lower at Fallon than the rest of the Fleet, indicating a significantly greater reduction in NSAWC air wing mishaps and suggests focused aviation mishap reduction efforts in similar circumstances could result in similar reductions.

Keywords: Human Factors Classification System, operational risk management, human factors, patient safety, risk management, flight surgeon pilot, dual designator, mishap, mishap reduction, carrier air wing.

THE NAVAL STRIKE and Air Warfare Center (NSAWC) located at the Naval Air Station Fallon (NASF) in Nevada is responsible for training, evaluating, and certifying carrier air wings (CVW) prior to aircraft carrier deployments. Every stateside air wing in the U.S. Navy goes to Fallon for 30 d prior to carrier deployments. There were five NASF Class A mishaps in 1998, tying the highest in recorded history. This led to 1998 being regarded as the "worst in recorded history for all Fallon aviation mishaps" (Fig. 1). This unique set of circumstances of a spike of mishaps followed by intense Human Factors Analysis and Classification System (HFACS) risk assessment and application of Operational Risk Management (ORM) precepts provided an opportunity to study the effects of focused mishap reduction efforts. This study attempts to evaluate the effect of applying retrospective HFACS-coded reports proactively and prospectively to military flight operations in the anticipation of reducing aviation mishaps.

ORM was introduced to the U.S. Air Force and U.S. Navy in 1995 and was an adaptation of a successful U.S. Army aviation mishap reduction process (11,13–15). ORM is a continual process-improvement decision-

making tool which includes risk assessment, decision making, implementation of risk controls (to accept, avoid, or mitigate risk), and continuous monitoring of outcomes. The goal of effective risk management is not so much to minimize particular errors and violations as to enhance human performance at all levels of the system (2,10).

HFACS is a way to study and categorize mishaps in order that interventions can be instituted to reduce human errors (8,11,13–15). HFACS is based on earlier research published in 1990 by Reason (9), who described active versus latent failures that humans made during nuclear accidents and shipboard mishaps. This theory was further developed by Shappell and Wiegmann to address aviation-specific mishaps (11,12). HFACS can be effectively used to assess risk as the first step of ORM (risk assessment) as well as a tool for continuous monitoring of outcomes (mishaps and mishap rates).

Department of Defense (DoD) aviation mishaps are defined as accidents where damage to the airplane is greater than \$10,000.00 (USD) or serious injury/death occurs. Of aircraft (military and civilian) mishaps, 70% to 90% are due to human errors (1,2,4–6). Human factors mishaps create considerable losses in aircraft and in priceless aircrew lives, both of which are vitally needed to support ongoing world-wide military operations (2,3). Furthermore, the potential benefits of an HFACS-informed approach to mishap reduction go well beyond that of aviation, as human error injuries in general are the single leading cause of deaths, disabilities, hospitalizations, outpatient visits, and manpower losses among military service members (7). A Class A mishap results when total damage exceeds \$1 million, the aircraft is destroyed, or fatal injury or permanent total disability occurs. This study will focus on Class A flight mishaps as they have the most information available through their mishap investigations, are routinely used in aviation as baseline data, and are the most costly with respect to

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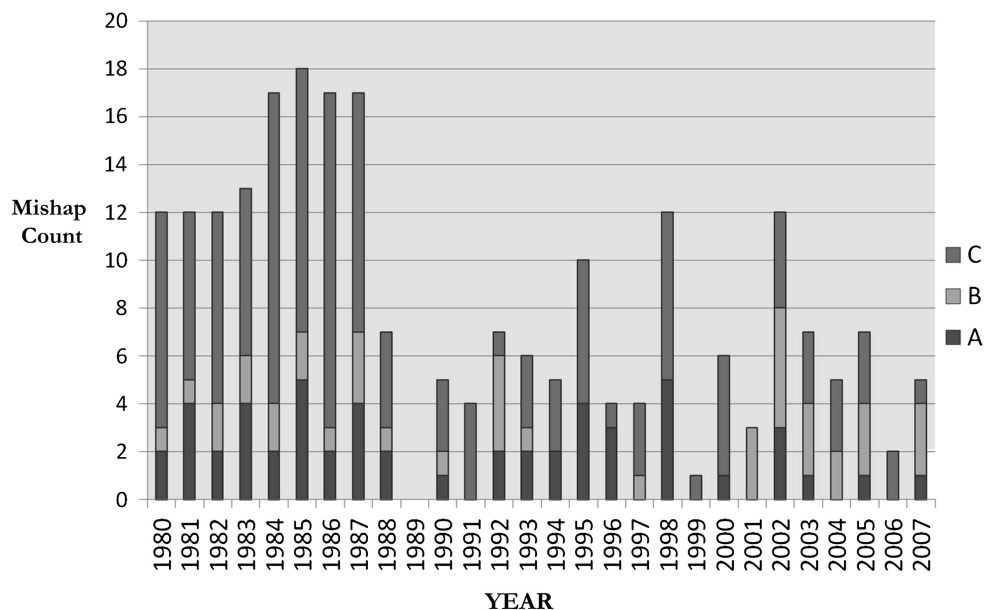


Fig. 1. Overall Fallon mishaps.

lives and material lost. At the time of this investigation, most of the lesser U.S. Navy aviation mishaps (Class B and Class C) had not been HFACS-coded. Additionally, the original 1998 U.S. Naval Safety Center HFACS evaluation of NASF mishaps only included Class A mishaps.

As a response to the spike in Fallon mishaps and upon request of the NSAWC Commanding Officer, the Naval Safety Center completed a thorough Class A HFACS review up through 1998. The analysis showed 70% of the 19 Class A mishaps, including all 3 helicopter mishaps, were influenced by some form of aircrew violations. Furthermore, the areas of crew resource management and proficiency vs. currency caused the majority of the remaining mishaps. Most, if not all, of these mishap types could theoretically be prevented with appropriate preflight briefs, planning, and attention to detail during the flight. These identified HFACS areas were used by NSAWC staff in their efforts to reduce carrier air wing mishaps.

With respect to mishap reduction efforts, there was a clear demarcation of efforts beginning after 1 June 1998. This was a time when NSAWC implemented sweeping changes in the way it approached mishap reductions by implementing multiple efforts, including ORM precepts. Mishap reduction efforts included a message from the NSAWC Commander, culture workshops, safety stand-downs, safety surveys, and a mandatory HFACS-informed ORM in-brief prior to Fallon flight operations. Beginning June 1998, 30 d prior to air wing detachments, the Commanding Officer of NSAWC would send a personal Navy message to every aircraft squadron Commanding Officer and aviator deploying to Fallon for work-ups. This message would emphasize the Naval Safety Center HFACS-identified highest risk areas and the HFACS attributes that could decrease the possibility of mishaps. In the message, the Commanding Officer stressed professionalism, working up to varsity level

flights, and ensuring that all aviators were qualified, current, and proficient for the level of flight difficulty they were scheduled to fly. This personal message to aircrew continues today and is focused on flight safety. Secondly, the NSAWC staff stressed a culture of safety by initiating command culture workshops, safety stand-downs, and safety surveys. Third, the NSAWC dual designated flight surgeon pilot developed an HFACS-informed ORM brief in response to the spike in mishaps that was mandatory for all aircrew to receive prior to flying at Fallon. The 45-min brief was given the first morning of the carrier air wing detachment to Fallon and occurred right after the Commanding Officers spoke, highlighting the importance NSAWC Command placed on mishap reduction efforts. This brief drew from the Naval Safety Center HFACS review of all prior Fallon Class A mishaps and stressed ways to avoid similar type-mishaps while on detachment. Additionally, the brief stressed professionalism and adherence to the flightpl an—to“fl y it like you brief it.”

METHODS

The methods and analysis plan were reviewed by a biostatistician and an epidemiologist from Uniformed Services University of the Health Sciences, and the study was determined to be a nonrandomized investigational study with use of a historical comparison population. The required number of flight hours in order to have a statistically significant result was determined prior to beginning the study using power analysis (assuming unexposed to exposed ratio 1:1, incidence of Class A mishaps before application of ORM of 3 per 10,000 flight hours, and power 80%, alpha of 5%). Approximately 35,000 flight hours per 9-yr period of time are required to detect a 90% risk reduction (odds ratio of 0.1). If the risk reduction is 80%, approximately 50,000 flight hours per 9-yr period would be required, and if the risk reduc-

tion is 50%, approximately 160,000 flight hours per 9-yr period would be required.

Study Population

The study population was U.S. Navy carrier air wing aviators who reported to Fallon, NV, during advanced phase work-ups prior to carrier deployment from 1 June 1998 to 31 May 2008. This carrier air wing aviator group is a subsection of all naval aviators that deploy to NASF over a normal year and was selected because it is a cohort that can more readily be studied as a group. While at NSAWC, carrier air wing sorties are tightly scheduled and rigorously regulated, with concomitant mishap data readily available.

Naval Safety Center HFACS Data

The research proposal to study air wing Fallon Class A mishaps was routed and approved by the Uniformed Services University of Health Sciences institutional review board. No consent was required as this information is covered by DoD safety regulations and can be used to study and improve DoD safety. Non-attributable historical data was obtained from the Naval Safety Center database. There was no risk to any humans and no personal data was made available to the researchers. In 1998, the U.S. Naval Safety Center was beginning to HFACS-code Naval Class A mishaps and had not progressed to code lesser mishaps, so at the time of the 1998 NASF mishap spike only Class A mishaps were scrutinized with HFACS.

Comparison Groups

The 10-yr comparison periods were: 1 June 1988–31 May 1998 versus 1 June 1998–31 May 2008. Upon request, the Naval Safety Center supplied all available recorded mishap data at and around NASF from 1980 to 31 May 2008, which included 235 mishaps of all types. Using these mishap reports, applicable air wing mis-

haps were selected in for analysis. Flight hours were obtained from the NSAWC analyst who closely tracked the flight hours and had been stationed at NSAWC since 1991, thereby having first-hand knowledge of most Fallon mishaps. Outcomes are Class A flight mishaps that occurred during air wing training at NSAWC (measured in Class A mishaps per 100,000 flight hours) (Fig. 2).

Statistical Analysis

Comparison data was pulled by the Naval Safety Center to show Fleet flight hours for the same carrier aircraft types as NSAWC (referred to as Fleet flight hours). Mishap rates in Fallon for 10 yr pre- and post-1 June 1998 were compared to U.S. Navy squadron (Fleet) levels of mishap rates. The “exposure” is HFACS-informed mishap reduction efforts discussed earlier in the paper. Poisson regression is appropriate when the dependent variable (mishap) is a count and the events are independent in that one mishap will not make another mishap more or less likely, but the probability per unit time of events is understood to be related to covariates such as time. Due to the low mishap (count) numbers and rates, the Poisson analysis method was chosen and STATA for Windows® (10.0) software was used for analysis.

RESULTS

A synopsis of data including mishaps, flight hours, and crude mishap rates per 100,000 flight hours can be seen in Table I. An analysis using Poisson regression of the combined Fleet and NSAWC data shows a 27% reduction in mishap rate ($P = 0.017$, 95% CI 0.57–0.95), but the reduction in the Fleet alone was not statistically significant at a 21% reduction ($P = 0.073$, 95% CI 0.61–1.02) (Table II). The mishap reduction at Fallon was statistically significant with an 84% reduction ($P = 0.015$, 95% CI 0.04–0.70) as well as the interaction term for Fleet * Fallon reduction of 80% ($P = 0.038$, 95% CI 0.04–0.91). The incidence rate ratio was 80% lower at Fallon than

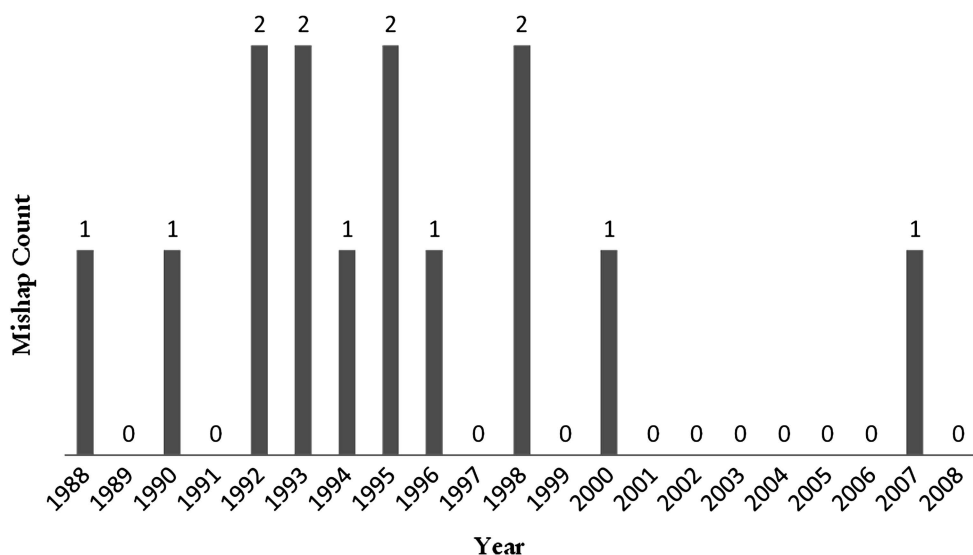


Fig. 2. Fallon carrier air wing Class A mishaps per year.

TABLE I. TIME BLOCK, EVENTS, FLIGHT HOURS, AND MISHAP RATES.

Time Block	Events (Mishaps)	Cumulative Flight Hours	Mishap Rate/100,000 Flight Hours
Fallon Air Wing 1 June 1988–31 May 1998	12	50,836	23.6
Fallon Air Wing 1 June 1998–31 May 2008	2	54,046	3.7
Fleet 1 June 1988–31 May 1998	126	4131,958	3.0
Fleet 1 June 1998–31 May 2008	100	4135,997	2.4

the rest of the Fleet, indicating a significantly greater reduction in NSAWC Air Wing mishaps. Fallon carrier air wing mishap rates post-ORM mishap reduction efforts are approaching those seen in the Fleet, but are still elevated overall (3.7 vs. 2.4). In summary, the analysis showed that there was a statistical decrease in Class A Fallon carrier air wing mishap rates approaching similar U.S. Navy squadron (Fleet) levels when comparing the 10 years prior to HFACS-informed mishap reduction efforts to the 10 years that followed. During the same time, even though HFACS and ORM were being applied to the Fleet, there was not a significant decrease in Fleet-comparable aircraft mishaps.

DISCUSSION

Some of the outside areas (potential confounders) that may have impacted the findings include the Navy's transition during the study period to newer aircraft, specific aviator demographics (gender, age, fatigue, flight hours flown, and currency), historical versus prospective data, regression to the mean concept, possible transient ORM impact, squadron member turnover, and the power of the study. During the time of this study, the Navy completed a transition from the F-14 Tomcat to the F/A-18 Hornet with its newer technology. This may have contributed to the mishap reductions seen at Fallon, although a similar significant reduction was not seen in the Fleet comparison group during this time, suggesting that the newer aircraft technology does not fully explain the reduction seen at NSAWC.

Specific aviator demographics of gender, age, fatigue, flight hours flown to date, and currency were not evaluated in this study, primarily due to the lack of this denominator data (aviator-specific flight hours broken out by variable). In addition, the low number of mishaps

and flight hours in the demographic subgroups would have resulted in an underpowered analysis of these variables. If evaluated, one would most likely find little to no influence on the mishap outcomes.

Historical data was used for the entire study. Therefore, the categorization of carrier air wing mishaps by causal factor and their inclusion into the study were open to some degree of interpretation. Ideally, a prospective study would eliminate much of this potential bias.

The 1998 spike in NSAWC mishaps could have actually been a random outlier and may not have been a true increase in the underlying rate of mishaps, as the following year there was a return to below baseline rate, otherwise referred to as a regression to the mean. In this scenario the NSAWC robust response may have been an over-reaction. However, the Fallon 10-yr comparisons (pre- versus post-10-yr) difference is statistically significant, suggesting that the difference goes beyond simple regression to the mean.

Two other potential confounders are the concepts of transient ORM impact and squadron turnover. ORM training effect may be transient or associated with the frequency/quality of the training. Helicopter Squadron 7 was the last squadron in 1998 to experience a Class A mishap at NASF and 9 yr later experienced a second NASF Class A mishap with causal factors that should have been mitigated by the NSAWC mishap reduction efforts. Most military assignments are 2 to 3 yr in length, so over a 3-yr period of time the squadron members/NSAWC instructors are entirely replaced by new members. This turnover can possibly result in a loss of corporate knowledge. In the case of Helicopter Squadron 7, the second mishap within 9 yr may have been related to a loss of corporate knowledge or a change in the briefing message provided at NSAWC. Because the sample size is small, it is difficult to assign any certainty to the concepts of transient ORM impact and/or squadron turnover.

Other explanations for the results are the intensity in which mishap reduction efforts were applied at NSAWC and the possibility that HFACS risks throughout other parts of the Fleet were different than those at NSAWC. It could be argued that although the Fleet was implementing HFACS/ORM, it was at a much less intense pace and with less urgency than at NSAWC due to the recent 1998 spike in Fallon mishaps. This could mean that the carrier air wing mishap reductions seen at NSAWC would not necessarily translate to mishap reductions in Fleet units. The ability to tightly control NSAWC carrier air wing training and relative isolation of NSAWC argue that what was seen at Fallon may in fact be due to a completely unique set of circumstances. If this is the case, then generalization to other aviation units would be difficult at best and similar interventions applied elsewhere could have minimal or no effect.

On the other hand, ORM may have been better suited for NSAWC vs. the Fleet when it comes to mishap reductions primarily due to the type of mishaps HFACS identified. At NSAWC the most common causes of mishaps as identified by HFACS were violations, crew resource management, and proficiency, all of which are

TABLE II. RESULTS: INCIDENCE RATE RATIOS.

	Incidence Rate Ratio	Incidence Rate Reduction	P-Value	Confidence Interval
Total (Fleet + Air Wing)	0.73	27%	* 0.017	0.57-0.95
Fleet	0.79	21%	0.073	0.61-1.02
Fallon Air Wing	0.16	84%	* 0.015	0.04-0.70
Fleet * Fallon Air Wing	0.20	80%	* 0.038	0.04-0.91

* Statistically significant.

arguably more susceptible to ORM precepts (risk assessment, decision making, implementation of risk controls, and continuous monitoring of outcomes) than risks seen in the Fleet (e.g., perceptual errors). Another germane observation is that during the same time period that a statistically significant reduction in Class A mishaps was seen there was an increase in Class B mishaps from 7 to approximately 19 for all of NASF (Fig. 1). One explanation is that although Class A mishaps were reduced, it was at the expense of more Class B mishaps. This elevation in Class B mishaps was not included in this study, did not separate out CVW Class B mishaps, and raises questions about the validity of the Class A mishap reductions observed at NSAWC. Further analysis would be needed to determine whether in the balance more Class B mishaps were preferable over Class A mishaps. What can be said with certainty is that there were two less lives lost (seven vs. five) between the two study periods, arguing that at least in lives, if not monetary analysis, the NSAWC mishap reduction efforts had an impact. Additionally, the study cannot rule out that "other things" that have not yet been considered may have actually caused the mishap reductions seen at NSAWC.

When all is said and done, although there were no carrier air wing Class A mishaps for nearly 3 yr after the implementation of NSAWC efforts, the mishap rate was still elevated when compared to similar Fleet aircraft types. It is widely accepted that the difficulty of flying at Fallon is only surpassed by actual combat flying and, as a result, an increased rate of mishaps over Fleet operations would normally be expected. However, during the same time periods there was a statistically significant reduction of mishaps at NSAWC not seen in the Fleet. The exact cause of this effect cannot be determined by this study, although the timing of increased HFACS-informed ORM efforts at NSAWC is compelling. Future prospective studies could better evaluate this hypothesized effect and potentially determine if HFACS-directed ORM efforts actually result in significant reductions in aviation mishaps.

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